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WO 1999/049610 A1
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WO 1999/048237 A1
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2000 International Symposium on Information Theory, Italy,25-30 June 2000, pub. IEEE, USA, page 109, Pursley M. et al, "Channel quality estimation with channel error counts for adaptive signaling in wireless communications"

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(54) Abstract Title
Assessing quality of channels in communications systems

(57) If a CRC checker 16 deems a signal 22 to be decoded correctly, then the decoded signal 22 can be re-encoded by a channel encoder 20 and compared to the received data sequence 10 input to the channel decoder 12. The comparison is performed by a measuring unit 14 which can then estimate propagation channel parameters such as the signal to noise ratio, the block error rate, and the uncoded bit error ratio.

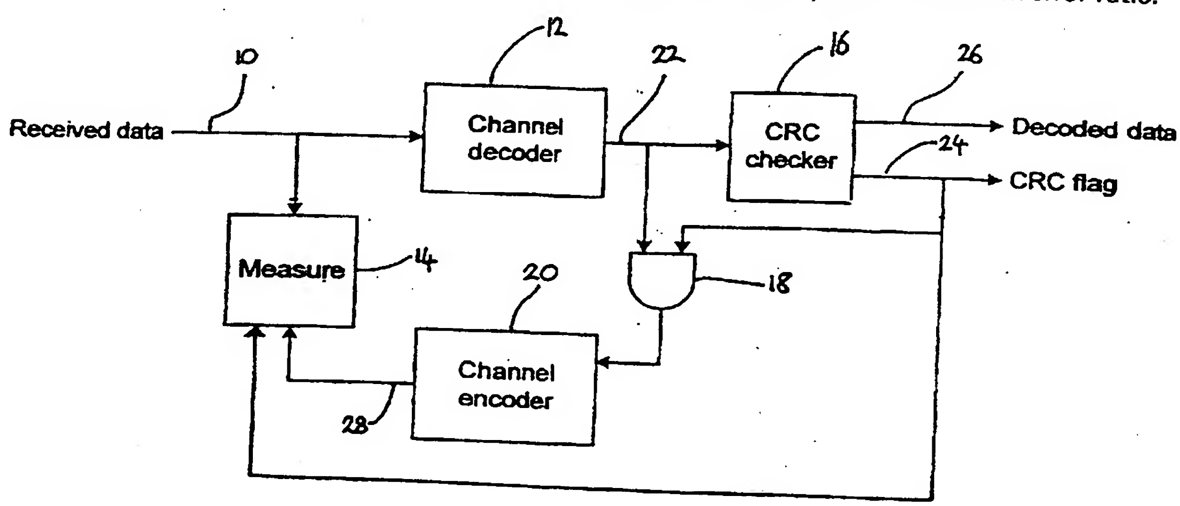

Figure 1

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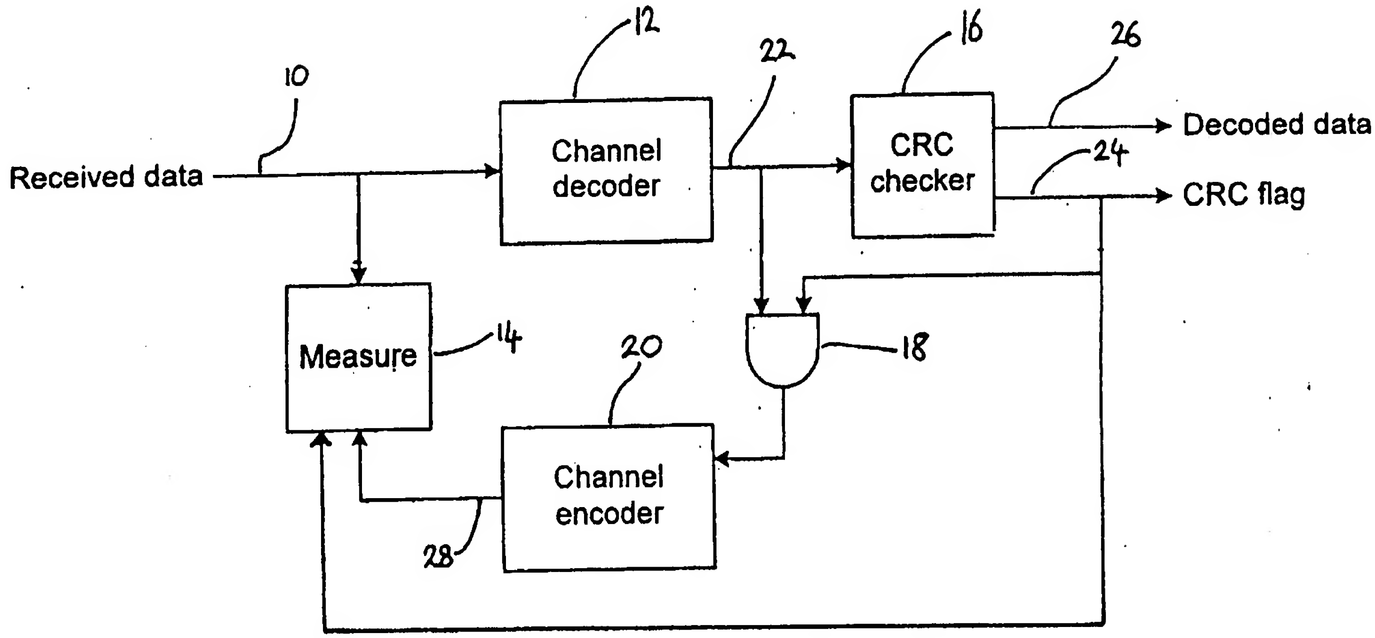
Received data
Channel decoder
CRC checker
Decoded data
CRC flag
Measure
Channel encoder
10
12
14
16
18
20
22
24
26
28

Figure 1

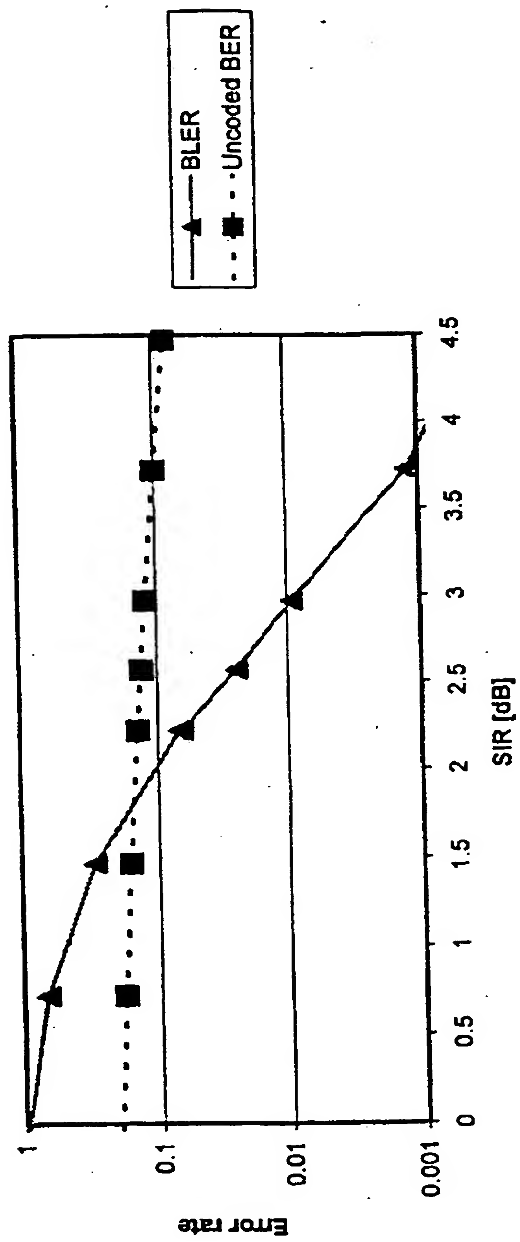
BLER
Uncoded BER
Error rate
1
0.1
0.01
0.001
SIR [dB]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

Figure 2

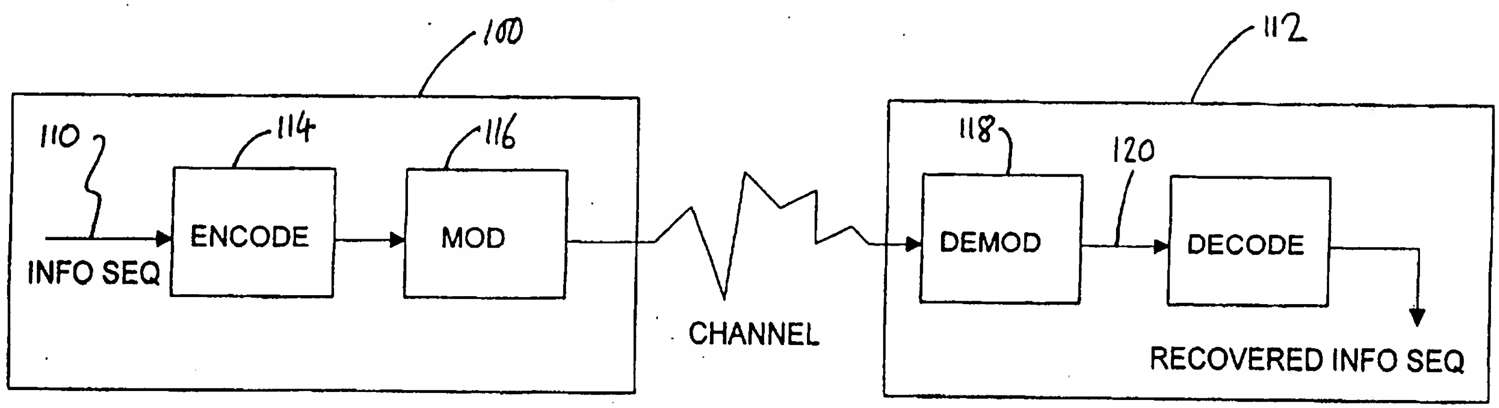
100
112
110
114
116
118
120
INFO SEQ
ENCODE
MOD
CHANNEL
DEMOD
DECODE
RECOVERED INFO SEQ

Figure 3

ASSESSING CHANNELS IN COMMUNICATIONS SYSTEMS

The invention relates to apparatus for and methods of evaluating channel conditions. In particular, the invention relates to evaluating channel conditions in a digital telecommunications system.

Figure 3 is a generalised schematic of a digital telecommunications system. In transmitter 100 an information sequence 110 to be transmitted to receiver 112 is encoded by channel encoder 114 which introduces a degree of redundancy into the bit stream. The redundancy added by the channel encoder 114 can be used at the receiver to overcome the effects of noise and interference in the channel between the transmitter and the receiver. The output of the channel encoder 114 is then processed by modulator 116 and the output of the modulator 116 is sent over a channel to the receiver 112.

The signal reaching the receiver 112 is demodulated by demodulator 118 to produce a received data sequence 120. The received data sequence 120 is then supplied to decoder 122 which uses the redundant information added by channel encoder 114 to recover the information sequence with enhanced reliability. It is possible to test the recovered information sequence to examine its reliability. For example, the information sequence may contain a data section and a cyclic redundancy checksum (CRC) such that a CRC check can be performed to determine if the CRC corresponds to the data section.

It is desirable to be able to assess parameters of a channel connecting a transmitter and a receiver and the invention aims to provide a way of performing such assessments.

According to one aspect the invention relates to a method of assessing a communications channel, comprising decoding a signal received via said channel and comparing a re-encoded version of the decoded signal with the received signal to assess the channel.

The invention also consists in apparatus for assessing a communications channel, comprising decoding means for decoding a signal received via said channel, re-encoding means for re-encoding the decoded signal and comparing means for comparing the re-encoded signal with the received signal to assess the channel.

In one embodiment, the comparison between the re-encoded and received signals is only made if there is sufficient confidence that the received signal was decoded correctly. In another embodiment, the comparison proceeds in the absence of a reference to said confidence level.

In one embodiment, the re-encoding of the decoded signal for the purpose of comparison only takes place if there is sufficient confidence that the signal has been decoded correctly. In another embodiment, the re-encoding of the decoded signal for the purpose of the comparison takes place regardless of whether there is sufficient confidence that the received signal was decoded correctly but the comparison only proceeds if said confidence exists.

In one embodiment, an error checking operation is performed on the decoded signal to assess the level of confidence that the decoding was successful. Preferably, this error checking operation comprises performing a CRC check on the decoded signal.

Various forms of comparison can be applied to the received and re-encoded signals. For example, these two signals can be used to calculate one or more channel parameters such as a signal to noise ratio, a block error rate or an uncoded bit error ratio.

In a preferred embodiment, at least one channel parameter is calculated from the received and re-encoded signals and a further channel parameter is selected using at least one calculated channel parameter. This can be achieved, for example, by storing values of a channel parameter in a look-up table and indexing the look-up table using values of a calculated channel parameter.

According to another aspect, the invention provides a method of determining a parameter of a communications channel, comprising using a value of a first channel parameter to index a store containing values of a second channel parameter thereby to select a value for the second channel parameter.

The invention also consists in apparatus for determining a parameter of a communications channel comprising a store containing values of a second channel parameter and means for indexing the store using a value of a first channel parameter thereby to select a value for the second channel parameter.

Thus the invention provides a way of determining channel parameters efficiently.

In one embodiment, the parameter in the store is a block error rate.

In one embodiment, a third channel parameter is also used in the indexing of the store.

The store can be indexed by, for example, at least one of an uncoded bit error rate and a signal to noise ratio.

The invention thus enables the estimation or calculation of channel parameters in a communications system. For example, such parameters can be used in an outer-loop power control loop in a UMTS system.

By way of example only, certain embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a measuring section within a receiver;

Figure 2 is plot inter-relating three channel parameters; and

Figure 3 is a generalised schematic of a digital telecommunications system.

In the UMTS receiver shown in Figure 1, a signal received at an antenna (not shown) is demodulated by a demodulator (not shown) to produce received data 10. The received data is supplied to both a channel decoder 12 and a measuring unit 14. The output of channel decoder 12 is supplied to both a CRC checker 16 and an AND gate 18. An output from the CRC checker 16 is supplied to both the AND gate 18 and to the measuring unit 14. 20. The channel encoder 20 receives the output of AND gate 18.

In operation, the channel decoder 12 operates on the received data 10 using the redundancy information in the received data 10 to recover an information sequence 22, which is then supplied to CRC checker 16 and AND gate 18. The information sequence 22 contains a decoded data section and a CRC. The CRC checker 16 operates on the information sequence to ascertain whether the CRC matches the decoded data section to assess the level of confidence as to whether the information sequence 22 has been decoded reliably by channel decoder 12. The CRC checker 16 outputs a CRC flag 24 which indicates whether or not the CRC matches the decoded data section. If the CRC flag 24 indicates that the information sequence passed the CRC check, i.e. the decoded data section matches the CRC, then there is reasonable confidence that the channel decoder 12 decoded the information sequence 22 correctly. The CRC checker 16 also forwards the decoded data section 26 for subsequent processing as necessary within the receiver.

AND gate 18 receives the information sequence 22 and the CRC flag 24. In essence, AND gate 18 acts like a switch for supplying the information sequence 22 to the channel encoder 20 only when the CRC flag 24 indicates that the information sequence passes the CRC check. Thus, the channel encoder 20 only operates on the information sequence 22 if the information sequence 22 passes the CRC check. The channel encoder 20 re-encodes the information sequence to produce a re-encoded sequence 28. The channel encoder 20 uses an encoding scheme which is complementary to the decoding scheme used by decoder 12. That is, the encoder 20 operates the encoding scheme which decoder 12 is designed to decode. Thus, given that encoder 20 operates on an information sequence that has a high probability of being correct, the re-encoded sequence 28 corresponds to what the received data sequence 10 should be in the absence of channel propagation errors. Thus, the measuring unit 14 can compare the received data sequence 10 and the re-encoded data

sequence 28 to make assessments about the propagation channel that conveyed the signal containing the received data sequence 10 to the receiver.

The measuring unit can use the received data sequence 10 and the encoded sequence 28 to estimate various parameters relating to the propagation channel.

For example, the measuring unit 14 can compare the signs of the received data sequence 10 and the re-encoded data sequence 28 to estimate the uncoded bit error ratio (BER) for that particular received data sequence. The BER is likely to be sufficiently accurate if accumulated and averaged over only a few transmission time intervals since the error ratio is quite high and hence one does not have to gather too much statistical information before the statistics become reliable. The following pseudo code gives an example of one way in which the BER measurement could be performed:

```
let r_k be the received data sequence
let e_k be the re-encoded data sequence

count = 0
for each r_k and e_k
        if not(sign(r_k) = = sign (e_k))
                count = count +1
        end if
end for
BER = count/length(r_k)
```

The measuring unit 14 can also use the received data sequence 10 and the re-encoded data sequence 28 to estimate the signal to interference ratio (SIR, also called the signal to noise ratio - SNR) for either a static channel with additive white Gaussian noise (AWGN) or even a Rayleigh faded channel with AWGN. Again, the measurements are likely to be sufficiently accurate if accumulated and averaged over only a few transmission time intervals and hence one does not have to gather too much statistical information before the

statistics become reliable. Some pseudo code for estimating for SIR in both Gaussian and Rayleigh channels is given below:

let r_k be the received data sequence

let e_k be the re-encoded data sequence

if channel = Gaussian

    K = 1

else if channel = Rayleigh

    K = 0.89

end if

$signal_{power} = mean(r_k \bullet e_k)/K$

$SIR = 10.\log_{10}(signal_{power}^2/(mean(r_k \bullet r_k) - signal_{power}^2))$

where • implies the dot-product. In practice if the channel is neither Gaussian nor Rayleigh but somewhere in-between then K may be required to be set to some intermediate value.

For a given channel, there is a one to one correspondence between values of SIR and uncoded BER so it is possible to provide a look-up table (LUT) linking these two parameters. Hence it is possible to infer the SIR with sufficient accuracy from the calculated uncoded BER. A LUT could be constructed which maps calculated SIR values to the block error rate (BLER). Alternatively, a LUT could be constructed which maps calculated uncoded BER values to BLER values. As a further alternative, calculated values of both the SIR and the uncoded BER could be used to map to BLER values in a look-up table. In all of these examples of look-up tables for calculating the BLER, there is a one to one correspondence between each BLER value and the calculated parameter value which indexes it or, as the case may be, the values of the set of calculated parameters that index it. It is a great benefit to be able to obtain BLER values through a look-up table since the BLER is required to be calculated to an accuracy of better than 10^{-3} which implies a measurement period based on CRC flags of at least $50/10^{-3} = 50000$ blocks. Clearly BLER estimation via a look-up table is much faster.

Figure 2 illustrates the relationship between uncoded BER, SIR and BLER for a convolutionally encoded sequence through an AWGN channel. It would be apparent how the one to one relationship between these parameters allows them to be linked via look-up tables.

CLAIMS

1. A method of assessing a communications channel, comprising decoding a signal received via said channel and comparing a re-encoded version of the decoded signal with the received signal to assess the channel.

2. A method according to claim 1, wherein said comparison is performed only if there is sufficient confidence that the decoding was correct.

3. A method according to claim 1 or 2, wherein the re-encoded version of the decoded signal is only produced if there is sufficient confidence that the decoding was successful.

4. A method according to any one of claims 1 to 3, wherein an error checking operation is performed on the decoded signal to assess the level of confidence that the decoding was successful.

5. A method according to claim 4, wherein the error checking operation comprises performing a CRC check on the decoded signal.

6. A method according to any preceding claim, wherein comparing the received and re-encoded signals involves determining at least one of a signal to noise ratio, a block error rate and an uncoded bit error ratio.

7. A method according to any preceding claim, comprising calculating at least one channel parameter from the received and re-encoded signals and using at least one calculated channel parameter to select another channel parameter.

8. Apparatus for assessing a communications channel, comprising decoding means for decoding a signal received via said channel, re-encoding means for re-encoding the decoded signal and comparing means for comparing the re-encoded signal with the received signal to assess the channel.

9. Apparatus according to claim 8, wherein the comparing means compares the two signals only if there is sufficient confidence that the received signal has been decoded correctly.

10. Apparatus according to claim 8 or 9, wherein the re-encoding means produces a re-encoded signal for the comparison means only if there is sufficient confidence that the decoding was successful.

11. Apparatus according to any one of claims 8 to 10, further comprising checking means for performing an error checking operation on the decoded signal to assess the level of confidence that the decoding was successful.

12. Apparatus according to claim 11, wherein the checking means is arranged to perform a CRC check on the decoded signal.

13. Apparatus according to any one of claims 8 to 12, wherein the comparing means is arranged to determine at least one of a signal to noise ratio, a block error rate and an uncoded bit error ratio on the basis of the received and re-encoded signals.

14. Apparatus according to any one of claims 8 to 13, wherein the comparing means is arranged to calculate at least one channel parameter from the received and re-encoded signals and to select another channel parameter using at least one calculated channel parameter.

15. A method of determining a parameter of a communications channel, comprising using a value of a first channel parameter to index a store containing values of a second channel parameter thereby to select a value for the second channel parameter.

16. A method according to claim 15, wherein a value of at least a third channel parameter is also used in the indexing of the store.

17. A method according to claim 16, wherein the third parameter is one of the uncoded bit error rate and a signal to noise ratio.

18. A method according to claim 15, 16 or 17 wherein the first parameter is one of the uncoded bit error rate and a signal to noise ratio.

19. A method according to any one of claims 15 to 18, wherein the second parameter is a block error rate.

20. Apparatus for determining a parameter of a communications channel comprising a store containing values of a second channel parameter and means for indexing the store using a value of a first channel parameter thereby to select a value for the second channel parameter.

21. Apparatus according to claim 20, wherein the indexing means is arranged to use a value of at least a third channel parameter in the indexing of the store.

22. Apparatus according to claim 21, wherein the third parameter is one the uncoded bit error rate and a signal to noise ratio.

23. Apparatus according to claim 20, 21 or 22, wherein the first parameter is one the uncoded bit error rate and a signal to noise ratio.

24. Apparatus according to any one of claims 20 to 23, wherein the second parameter is a block error rate.

25. A program for causing data processing equipment to perform the method of any one of claims 1 to 7 or 15 to 19.

26. A method of assessing a communications channel, substantially as hereinbefore described with reference to the accompanying figures.

27. Apparatus for assessing a communications channel, substantially as hereinbefore described with reference to the accompanying figures.

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Claims searched: 1-14,25-27

Examiner: Steven Davies
Date of search: 26 June 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): H4P-PEM

Int Cl (Ed.7): H04L-1/20

Other: Online databases: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2305083 A	(MOTOROLA) e.g. Fig.1 ; page 3, line 6 - page 4, line 16	1,6,7,8, 13,14,25
X	EP 0648032 A1	(NOKIA) e.g. Fig.1; page 3, lines 9-29	1,6,13,14, 25
X	WO 99/49610 A1	(CONEXANT) e.g. Fig.2 ; page 6, line 6 - page 7, line 3	1-6,8-13, 25
X	WO 99/48237 A1	(NOKIA) e.g. Figs.3,4 ; page 6, lines 16-32 ; page 7, line 31-page 9, line 4	1-14,25
X	US 6163571	(ASOKAN) e.g. column 4, lines 27-40 ; column 7, para.1	1,6,7,8, 13,14,25
X	US 4967413	(OTANI) e.g. Fig.5 ; column 4, lines 30-49	1,6,8,13, 25
X	2000 IEEE International Symposium on Information Theory, Sorrento, Italy, 25-30 June 2000, pub 2000, Piscataway, NJ, USA, IEEE, USA , page 109, Pursley M. et al, "Channel quality estimation with channel error counts for adaptive signaling in wireless communications"		1,6,7,8, 13,14,25

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